Audio Hiding in Color Image Using SLT Schemes

Asmaa abdul-Razzaq AL-qaisi*

Department of Computer Science, College of Education for Women, University of Baghdad, Baghdad, Iraq

Abstract:

As usage of internet grows in different applications around the world, many techniques were developed to guard an important data against from illegal access and modification from unauthorized users by embedding this data into visual media called host media. Audio hiding in an image is a challenge because of the large size of the audio signal. Some previous methods have been presented to reduce the data of the audio signal before embedding it in the cover image, however, these methods was at the cost of reducing the quality of the audio signal. In this paper, a Slantlet transform (SLT) based method is applied to obtain better performance in terms of audio quality. In addition, the data hiding scheme in the cover color image has been implemented using SLT matrix method. The simulation results prove that the proposed algorithm produce better performance in terms of audio quality and execution time in comparison with the existing DWT based schemes. Also, the proposed data hiding scheme takes good visual quality results and high data hiding capacity.

Keywords: Information Security, Slantlet Transform, Audio Hiding.

اخفاء الصوت داخل الصور الملونة باستخدام (SLT) Slantlet transform

أسماء عبد الرزاق القيسي*

قسم الحاسبات، كلية التربية للبنات، جامعة بغداد، بغداد، العراق

الخلاصة

على مر السنين،عُرضت مختلف تقنيات اخفاء البيانات لتوفير الامن عند تبادل المعلومات الحساسة من خلال قناة غير امنـــة مثل الانترنت،ان اخفاء اشارة صوتية في صورة مثال على تقنيات اخفاء البيانات المرغوب فيه حيث يشكل تحديا نظرا لكبر حجم الاشارات الصوتية .

تم عرض بعض الاساليب السابقة للحد من بيانات الاشارات الصوتية قبل التضمين في صـورة الغـلاف ،ومـع ذلك كانـت هـذه الاساليب على حساب خفض جودة الاشارة الصوتية ،في هذا البحث يعتبر (SLT)Slantlet transform كطريقة للحصول على أداء أفضل من حيث جودة الصوت، بالاضافة الى ذلك تم تنفيذ مخطط اخفاء البيانات في صورة الغلاف الملون باستخدام (SLT) طريقة المصفوفة واثبتت النتائج ان الخوارزمية المقترحة تم من خلالها الحصول على أداء افضل من حيـث جودة الصوت والتنفيذ والوقت بالمقارنة مع مخططات DWT عليها ، كذلك فان مخطط اخفاء البيانات المقتـرحة ذو نتائـج جيدة والـقدرة على اخـفاء البيانات عالية.

1- Introduction

The increased use of internet to share digital information brings with it more needs for security when exchanging this information. Data hiding techniques are examples on the methods that have been used to provide security in information transmission systems. Steganography [1] and digital watermarking techniques [2] are the two main parts of the data hiding techniques. In these techniques,

_____

*Email:alqaisi_asmaa@yahoo.com

the secret data is hidden in a cover data (e.g., text, image, audio, and video) for different purposes such as making the secret information invisible [3], protecting the cover data from manipulation [4], copyright protection [5], etc.

2- Related Works

Several data hiding schemes have been implemented for different applications. Some schemes used an audio signal as a cover media to carry secret data (e.g., audio, image, and text). In [6], a new approach of embedding watermarking into digital image using slantlet transform has been presented. This method embeds the watermarking into mid band frequencies of slantlet coefficients in the transform domain. In [7], an audio steganography system is proposed to hide a sequence of binary digits in digital audio data based on applying AM technique on wavelet transform coefficients. The embedding system implies partitioning the audio signal (cover) into a number of non overlap slices

In general, steganography schemes have been implemented to hide a secret audio signal in a cover image. In [8], short audio signal has been embedded in the LSB of the cover image. The scheme obtained high visual quality, however, the LSB methods are very sensitive to any kind of image manipulation and can easily be destroyed as mentioned in [8].

In [9], a LSB data-hiding approach is presented based on auto-key generator. For significant performance the cover file is lossless compressed file. In [10], the same idea of compressing the audio signal has been employed but the embedding process is different. The approximation coefficients of the audio signal have been embedded in the LSBs of the IWT coefficients of the cover image.

3- Problem Statement

The method that has been applied in [9] and [10] reduced the information of the audio signal before embedding it in the cover image, however, the effect of using this method on the quality of the audio signal has not been highlighted sufficiently. Based on recent researches [11-13] the Slantlet transform (SLT) [14] obtained better performance in comparison with the DWT based applications.
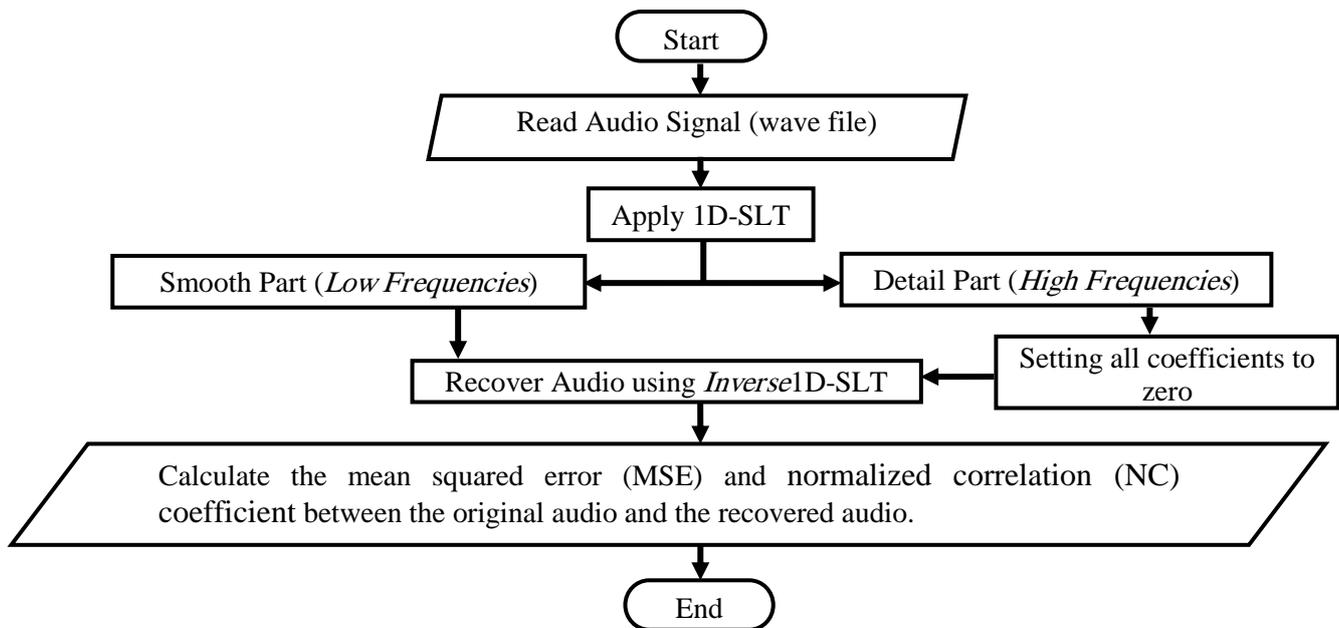
4- Proposed Audio Hiding Scheme

In this paper, the SLT is applied to reduce the audio information with better quality of audio. The effect of applying this method is evaluated and compared with the DWT based methods. For data hiding process, a SLT matrix based method is applied to obtain better performance in terms of visual quality.

The audio files contain large number of samples even for small period, so for the purpose of hiding audio signal in an image, the cover image should be considerably large [10] in addition the audio information must be reduced before embedding. The method used in [9,10] reduced the audio information by transforming the audio signal using DWT and choosing only approximation coefficients to be hidden in the cover image. The effect of applying this method on the quality of the audio signal has not been studied in [9, 10]. Our quantitative and qualitative studies of this method proved that this method reduced the quality of the audio signal. In order to reduce the audio information and recover the audio signal with better quality, this paper suggests the use of one dimensional Slantlet transform (1D-SLT) instead of the DWT. The reduced information of the audio signal is embedded in a cover color image based on SLT matrix. The next subsection explains the details of the proposed algorithm to reduce the audio information. The second subsection contains the details of the overall proposed audio hiding and extraction algorithms.

4.1. Proposed Audio Information Reduction Algorithm

The proposed method of this part depends on applying 1D-SLT on the audio signal. The approximation coefficients are chosen to be hidden in the cover image. The following flowchart has been implemented to study the performance of the proposed audio reduction method before applying it in the proposed audio hiding scheme:

```
                          ┌─────────┐
                          │  Start  │
                          └─────────┘
                               │
                               ▼
              ┌──────────────────────────────────┐
              │   Read Audio Signal (wave file)   │
              └──────────────────────────────────┘
                               │
                               ▼
                     ┌──────────────────┐
                     │  Apply 1D-SLT     │
                     └──────────────────┘
                               │
        ┌──────────────────────┴────────────────────────┐
        ▼                                                ▼
┌───────────────────────────┐          ┌───────────────────────────┐
│ Smooth Part (Low Frequencies) │      │ Detail Part (High Frequencies) │
└───────────────────────────┘          └───────────────────────────┘
        │                                                │
        │                                                ▼
        │                              ┌──────────────────────────────┐
        │                              │ Setting all coefficients to   │
        │                              │           zero                │
        │                              └──────────────────────────────┘
        ▼                                                │
┌──────────────────────────────────────┐◄───────────────┘
│  Recover Audio using Inverse1D-SLT    │
└──────────────────────────────────────┘
                     │
                     ▼
┌──────────────────────────────────────────────────────────────┐
│ Calculate the mean squared error (MSE) and normalized          │
│ correlation (NC) coefficient between the original audio and     │
│ the recovered audio.                                            │
└──────────────────────────────────────────────────────────────┘
                     │
                     ▼
              ┌─────────┐
              │   End   │
              └─────────┘
```

The results of this flowchart and the comparisons with the wavelet based methods are shown in section 5 (Experimental Results and Discussion).

4.2. Proposed Audio Hiding and Extraction Algorithms

The proposed audio hiding scheme based on the basic ideas of the watermarking schemes that have been presented in [11-13] but the overall steps are different. In this paper, the algorithm starts by applying the audio reduction algorithm that has been explained in section (2.1). To transform the cover image, SLT matrix method [12] is employed and for the audio bits hiding the SLT coefficients are modified according to the value of the input bit. The previous schemes in [11-13] have been applied to grayscale images; in this paper, the cover image is color therefore some steps have been added to deal with this type of images. The details of the proposed audio hiding and extraction processes are explained as follows.

A)   Audio hiding in cover image

1-   Read audio signal and cover image.

2-   Start audio processing steps:

a)   Transform audio signal (A) using 1D-SLT scheme.

$$s = SLT\{A\}$$

Where s is the Slantlet transform coefficients of the audio signal (A).

b)   Separate the resultant SLT coefficients into two equal parts ($s=\{s_A , s_D\}$). The low frequency coefficients are considered as the approximation part and the high frequency coefficients are considered as the details coefficients.

c)   Choose the approximation coefficients (s_A) to be embedded in the cover image. The details coefficients (s_D) will be considered as zeros at the audio recovery side.

d)   Convert the selected approximation coefficients to binary sequence ($binSeq$) which will be hidden in the cover image.

3-   The cover image is RGB color which means there are three channels that can be used to carry the secret audio bits. First, the algorithm calculates the available embedding capacity according to the size of the cover image as follows:

a)   Choose Red channel and divide it into non-overlapping blocks of size (16×16).

b)   Calculate the capacity. According to the rules in [11-12], each (16×16) block can carry 64 bits. Therefore, the total capacity is calculated as follows:

$$Total\ Capacity\ (C) = Total\ no.\ of\ blocks\ in\ one\ channel \times 64 \times 3$$

c)   Compare the payload(i.e., the length of the binary sequence ($binSeq$))with the available capacity (C) in order to check if there is enough capacity to carry the binary bits or not.

if the capacity < payload Then the algorithm shows a message "No enough capacity" and ends the execution.

if the capacity ≥ payload Then the algorithm continue to the following steps.

4-   Start embedding the binary bits in the three channels of the image sequentially. Each channel will carry the binary bits as follows:

a)   Divide the channel of the cover image into non-overlapping blocks of size (16×16).

b)   Transform each block using SLT matrix method [12] as follows:

$$TB = [SLT_{16}] [B] [SLT_{16}^T].$$

Where B is the original block, TB is the transformed block, and SLT_{16} is the Slantlet transform matrix of size 16×16.

c)   Divide the coefficients in TB into four subbands (LL, HL, LH, and HH).

Embed binary sequence (*binSeq*) by modifying the HL and LH subbands. The rules of the SLT coefficients modification are as follows:

$$If\ binSeq(i) = 1\ and D_1 = HL(x,y) - LH(x,y) < T,$$

(whereT is a threshold to control the invisibility), then increase HL(x,y) while decrease LH(x,y) by inserting the bit:

$$\begin{cases} HL'(x,y) = HL(x,y) + \dfrac{(T - D1)}{2} \\ LH'(x,y) = LH(x,y) - \dfrac{(T - D1)}{2} \end{cases}$$
$$Elseif\ D_1 = HL(x,y) - LH(x,y) \geq T, do nothing;$$
$$If\ binSeq(i) = 0\ and D_2 = LH(x,y) - HL(x,y) < T,$$
$$Similar\ operation\ is\ done:$$
$$\begin{cases} HL'(x,y) = HL(x,y) - \dfrac{(T - D2)}{2} \\ LH'(x,y) = LH(x,y) + \dfrac{(T - D2)}{2} \end{cases}$$
$$Elseif\ D_2 = LH(x,y) - HL(x,y) \geq T, do nothing.$$

This process is repeated to embed a binary sequence of length 64 bits. Thus, each spatial domain block of size 16×16 pixels can carry 64 bits.

d)   Replace the original horizontal and vertical high frequency coefficients with the modified coefficients.

e)   Apply inverse SLT to obtain the stegochannel using:

$$B_{new} = [SLT_{16}^T] [TB_{new}] [SLT_{16}].$$

Where B_{new} is the stego spatial domain block, TB_{new} is the stego transform domain block, and SLT is the Slantlet transform matrix.

f)   The original cover channel is replaced by the stego channel to obtain the stego cover image. The stego image with the length of *binSeq* are sent to the receiver side.

B)   Audio extraction from cover image

1)   Read the stego image.

2)   Extract the embedded bits from each channel as follows:

a)   Read the channel and divide it into non-overlapping blocks of size (16×16).

b)   Transform each block using SLT matrix.

c)   Divide the coefficients into four subbands (LL*, HL*, LH*, and HH*).

d)   Apply the following rules to extract the binary bits from HL* and LH* subbands:

$$binSeq^*(i) = \begin{cases} 1, & if HL^*(x,y) \geq LH^*(x,y) \\ 0, & if LH^*(x,y) > HL^*(x,y) \end{cases}$$

3)   Convert the binary sequence to float numbers to recover the approximation coefficients of the audio signal.

4)   Consider the details coefficients as zeros.

5)   Apply inverse Slantlet transform (1D-ISLT) to recover the hidden audio signal.

6)

5-   Experimental Results and Discussion

   This section presents the experiments that have been conducted to evaluate the proposed scheme. The first subsection, presents the experimental results for evaluating the proposed audio reduction

algorithm. The second subsection presents the experimental results of the proposed audio hiding scheme.

5.1. Evaluation Results of Audio Reduction Algorithm

For evaluating the proposed audio reduction algorithm that has been explained in section (2.1) it has been applied for different audio signals and the performance has been evaluated and compared with that of the DWT based methods from [9, 10]. Table-1 shows the results of the Mean Squared Error (MSE) between the original audio signal and recovered audio signal, the Normalized Correlation coefficient (NC) defined below which computes the similarity factor between original watermark and extracted watermark, and the execution time. To make the comparison valid, the two methods have been compared at the same number of approximation coefficients. As illustrated in Table-1, the proposed algorithm performs much better than the DWT based methods. The proposed algorithm obtained less MSE values and higher NC values in comparison with the results of the DWT based technique which means the proposed algorithm can recover the audio signal with better quality. The proposed algorithm required less time as shown in the execution time results. In addition, subjective evaluations have been conducted which also proved that the quality of the recovered audio signal using the proposed algorithm is much better than that of the DWT based recovered audio signal.

$$NC = \frac{\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}(W(x,y)) \times (WR(x,y))}{\sum_{x=0}^{m-1}\sum_{x=0}^{m-1}W(x,y)^2}$$

Where W(x, y) is the original watermark and WR(x, y) is the reconstructed watermark.

Table 1- Comparison results of audio quality and execution time

Audio signals (.wav)	MSE		NC		Execution Time	
	DWT based methods [9]&[10]	Proposed method using SLT	DWT based methods [9]&[10]	Proposed method using SLT	DWT based methods [9]&[10]	Proposed method using SLT
AE-Female 1	48.20×10^{-5}	1.19×10^{-5}	0.706	0.993	0.0689	0.0301
AE-Female 2	60.73×10^{-5}	3.18×10^{-5}	0.706	0.986	0.0692	0.0302
AE-Male 1	54.39×10^{-5}	4.30×10^{-5}	0.706	0.979	0.0838	0.0501
AE-Male 2	51.66×10^{-5}	3.98×10^{-5}	0.707	0.980	0.0697	0.0315
E-Female 1	77.04×10^{-5}	5.19×10^{-5}	0.707	0.998	0.1282	0.0939
E-Female 2	59.69×10^{-5}	2.65×10^{-5}	0.707	0.988	0.1279	0.0930
E-Male 1	40.08×10^{-5}	0.93×10^{-5}	0.707	0.994	0.1284	0.0909
E-Male 2	67.48×10^{-5}	0.23×10^{-5}	0.707	0.999	0.1305	0.0931

5.2. Evaluation Results of Audio Hiding Scheme

The proposed audio hiding scheme has been evaluated using different cover images with different size and a specific sample audio signal has been hidden in these cover images. Figure-1 shows test images with their corresponding stego-images where the pay load is 524288 bits.

For quantitative study the visual quality of the stego images has been evaluated using Peak-Signal-to-Noise-Ratio for color images ($PSNR_c$)as follows:

$$PSNR_c = \frac{\sum_{i=1}^{3} PSNR_i}{3} \quad .$$

Where i=1 for R channel, i=2 for the G channel, and i=3 for the B channel. The $PSNR_i$ denotes the peak signal to noise ratio of the ith channel, which is calculated as follows:

$$PSNR_i = 10\log\frac{M \times N \times \max\{[H(x,y,i)]^2\}}{\sum_{x=1}^{M}\sum_{y=1}^{N}[H(x,y,i) - H^{'}(x,y,i)]^2} \quad .$$

Where $H(x,y,i)$ are $H^{'}(x,y,i)$ the pixel values of the original image and the stego image in the location (x,y) of the specified i channel.

Table-2 contains the results that have been obtained from the experiments of evaluating the visual quality and the capacity of the proposed audio hiding scheme. As illustrated in the results, the proposed scheme obtained high visual quality and high data hiding capacity.
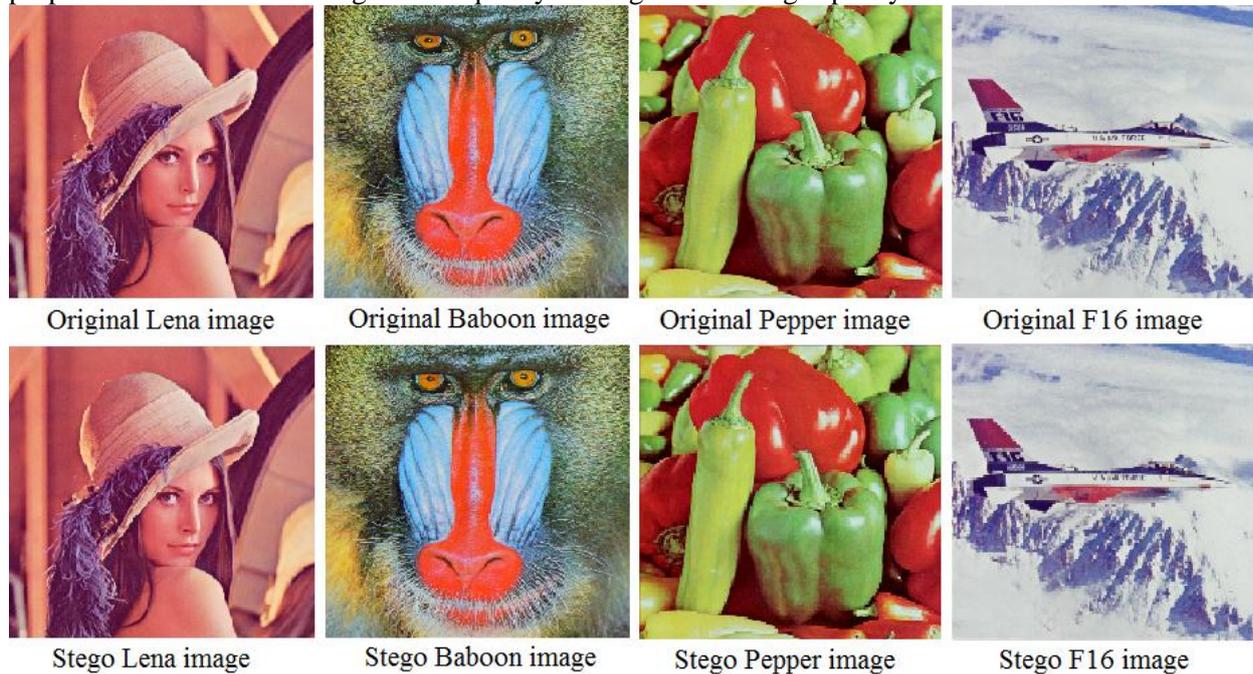

Figure 1- Original cover images and their corresponding Stego image (payload=524288 bits)

Table 2- Visual quality and capacity of the proposed audio hiding scheme

RGB color image	Size of image	Payload (bits)	Capacity (bits)	PSNR (dB)	MSE
Lena	1048×1000	524288	773760	42.8247	3.3932
Baboon	1000×1000	524288	738048	36.1951	15.6160
Pepper	1048×1048	524288	811200	42.0678	4.0393
F16	900 ×1048	524288	698880	42.0311	4.0735

6- Conclusions

In this paper, an approach of hiding audio signal into digital cover color image has been proposed. The size of the audio signal is reduced using 1D-SLT as a preprocessing step to minimize hiding data in the cover image which produces good quality stego image. The Slantlet transform based data hiding schemes have been considered as better candidates in comparison with the DWT based schemes in terms of visual quality of the cover image. Two evaluation scenarios are conducted to validate the performance of the proposed approach. First scenario is to evaluate the quality of audio signal after reduction using different samples of audio signals. Second scenario is to evaluate the quality of reconstructed image using different color images with variant sizes and specific audio signal. The simulation results in both scenarios prove the robustness of the proposed approach to perform better performance with respect to the well-known related works in literature in terms of standard evaluation metrics.

References

1. Souvik Bhattacharyya, Indradip Banerjee and Gautam Sanyal.**2011**.A Survey of Steganography and Steganalysis Technique in Image, Text, Audio and Video as Cover Carrier, *Journal of Global Research in Computer Science*, 2(4).
2. Baisa L. Gunjal and R.R. Manthalkar . **2010**. An overview of transform domain robust digital image watermarking algorithms, *Journal of Emerging Trends in Computing and Information Sciences*, 2(1).
3. Deepthi S., Renuka A. and Hemalatha S. **2013**. Data Hiding in audio signals using wavelet transform with enhanced security, Natarajan Meghanathan: ITCSE, ICDIP, ICAIT – 2013, pp:137–146.

4. Ratha, N.K., Connell, J.H., Bolle, R.M. **2001**.Enhancing security and privacy in biometrics-based authentication systems, *In IBM Systems Journal*, 40(3), pp:614-634.
5. Hsiang-Cheh Huang, Wai-Chi Fang. **2010**. Metadata-based image watermarking for copyright protection, Simulation Modeling Practice and Theory, 18(4), pp:436-445.
6. M. M. Lafta and I. M. Alwan. **2011**. Watermarking in image using Slantlet transform*, Iraqi Journal of Science*, 52, pp:225-230.
7. L. E. George and G. A. Mahmood. **2010**.Audio Steganography Based on Signal Modulation in Wavelet Domain, *Energy*, 9, p:10.
8. Khalil, M.I. **2011**. Image Steganography: hiding short audio messages within digital images, *Journal of Computer Science & Technology*, 11(02).
9. I. J. Kadhim. **2011**. A New Audio Steganography System Based on Auto-Key Generator, *AL-Khwarizmi Engineering Journal,* 8, p:155-163.
10. S. Hemalatha, U. Dinesh Acharya, and A. Renuka. **2015**. Wavelet Transform Based Steganography Technique to Hide Audio Signals in Image, *Procedia Computer Science*, 47, pp:272-281.
11. R. T. Mohammed and B. E. Khoo. **2012**. Image watermarking using slantlet transform, *IEEE Symposium on Industrial Electronics and Applications (ISIEA)*, pp:281–286.
12. R. Thabit and B. E. Khoo. **2014**. Robust reversible watermarking scheme using slantlet transform matrix, *Journal of Systems and Software*, 88, pp:74–86.
13. R. Thabit, and B. E. Khoo. **2014**. Capacity improved robust lossless image watermarking, *IET Image Processing*, 8(11), pp:662-670.
14. Selesnick, I.W.**1999.**The slantlet transform, *IEEE Transactions on Signal Processing*, 47(5), pp:1304-1313.